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COMPARISON OF STOMATAL CONDUCTANCE APPROACHES IN JSBACH

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INTRODUCTION

New stomatal conductance functions are implemented in the JSBACH land surface model and tested on a single site, that is the SMEAR II station in Hyytiälä, Finland. The purpose is to compare the new functions to the previously implemented functions in terms of the predictions they yield, and ultimately to see whether the implementation of the new functions could improve JSBACH on a more general level.

MODELS AND DATA

The JSBACH land surface model is the land component of the Earth system model MPI-ESM. Knauer *et al.* (2015) implemented four alternative stomatal conductance functions into JSBACH, tested them and compared the results to those yielded by the function**s** initially used in JSBACH.

In this study we compare three stomatal control functions: USO, CAP-V and CAP-L. USO stands for Unified Stomatal Optimisation (Medlyn et al. 2011). From Dewar *et al.* (2018) we take the general framework as well as the optimisation hypothesis in which the non-stomatal limitations to photosynthesis affect stomatal conductance directly (the CAP hypothesis). To obtain CAP-V, we combine this with the photosynthesis model proposed by Vico *et al.* (2013) in which the two branches of the Farquhar model are interpolated to produce a single, continuously differentiable function for the photosynthesis rate. CAP-L is the combination of the CAP hypothesis and the light-limited regime of the photosynthesis model by Farquhar et al. (1980).

The resulting stomatal control models resemble each other closely, but the CAP-based functions have more detail in terms of sensitivity to tree and soil properties and environmental drivers. Formulated as functions of the optimal photosynthesis rate, the three models yield the following formulae (see Table 1 for meanings of symbols):

The USO model: $$g_s^U \approx g_0^U + \left(1 + \frac{g_1^U}{\sqrt{D}}\right)\frac{A}{C_a}$$

The CAP-V model: $$g_s^V \approx g_0^V + \left(1 + g_1^V \sqrt{\frac{K P|\Psi_0|}{1.6 D}\left(\frac{k_m}{V_{cmax}} + \frac{4\Gamma_*}{J(Q)}\right)}\right)\frac{A}{C_a}$$

The CAP-L model: $$g_s^L \approx g_0^L + \left(1 + g_1^L \sqrt{\frac{K P|\Psi_0|}{1.6 D}\left(\frac{12\Gamma_*}{J(Q)}\right)}\right)\frac{A}{C_a}$$

This functions were implemented into the JSBACH photosynthesis module, after which a stand-alone (offline) version of JSBACH with climate forcing data was run on a single grid cell representing the

SMEAR II station in Hyytiälä. The parameters g_0 and g_1 for both models were fitted against the climate forcing data to produce the smallest cumulative error in relation to observations. The observation data used for the run was from the FLUXNET2015 dataset, in between 2001 and 2012.

RESULTS

All of the stomatal conductance functions produce mostly very similar results. In both evapotranspiration (ET) and gross photosynthetic production (GPP) the predictions go closely hand in hand at almost all times, but during dry periods there are more notable differences. The drought of August 2006 (Figure 1) produces a swift drop in ETT in CAP-V and a slower drop in USO, but an inverse reaction in CAP-L. During the drought GPP also drops in all of the models, fastest in CAP-V and slowest in CAP-L.

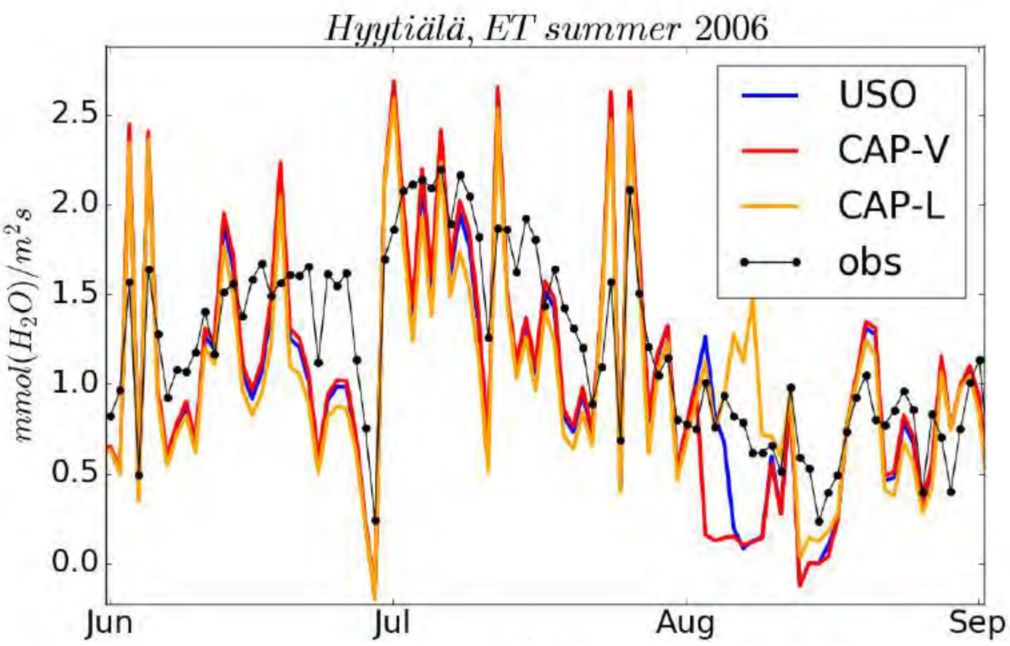

Figure 1. Evapotranspiration predictions for the summer of 2006 at SMEAR II using the USO (blue line), CAP-V (red line) and CAP-L (orange line) stomatal conductance models. Observations in black. The drought in August has a strong effect on the predictions.

Symbol	Meaning
A	photosynthetic rate
C_a	carbon dioxide concentration of ambient air
D	vapour pressure difference between the air inside and outside the leaf
$g_0^V, g_0^L g_0^U$	residual conductances for CAP-V, CAP-L and USO respectively
$g_1^V, g_1^L g_1^U$	fitted parameters for CAP-V, CAP-L and USO respectively
$g_s^V, g_s^L g_s^U$	optimal stomatal conductances for CAP-V, CAP-L and USO respectively
J	electron transport rate
k_m	Michaelis-Menten coefficient related to the Farquhar photosynthesis model
K	hydraulic conductance from soil to leaf
P	ambient air pressure
Q	incident photosynthetically active radiation
V_{cmax}	carboxylation capacity
Γ_*	CO_2 compensation point
Ψ_0	leaf water potential at which photosynthesis stops due to drought

Table 1. Meanings of symbols.

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